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RESRAD Connection for Facilitating MARSSIM Analysis: An Illustration of Applying the OpenLink Concept

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The following is a list of the acronyms, initialisms, and abbreviations (including units of measure) used in this document.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

ALARA	as low as reasonably achievable
CEDE	committed effective dose equivalent
CFR	Code of Federal Regulations
DCGL	derived concentration guideline level
DCGL-W	derived concentration guideline-wide area
DOE	U.S. Department of Energy
DQO	data quality objective
EDE	effective dose equivalent
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
NRC	U.S. Nuclear Regulatory Commission
RESRAD	RESidual RADioactivity (model)
TEDE	total effective dose equivalent

UNITS OF MEASURE

Bq	becquerel(s)
g	gram(s)
kg	kilogram(s)
m^2	square meter(s)
mrem	millirem(s)
mSv	millisievert(s)
pCi	picocurie(s)
yr	year(s)

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RESRAD CONNECTION FOR FACILITATING MARSSIM ANALYSIS: AN ILLUSTRATON OF APPLYING THE OPENLINK CONCEPT

by

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ABSTRACT

The focus of this work is to more tightly integrate tools traditionally used in MARSSIM (Multi-Agency Radiation Survey and Site Investigation Manual) final status survey design. MARSSIM provides guidance on appropriate methodologies for establishing that dose or risk-based standards for a site contaminated with radionuclides have been achieved. RESidual RADioactive (RESRAD) codes are used by the U.S. Department of Energy, the U.S. Nuclear Regulatory Commission, and other federal agencies to convert dose-based cleanup criteria to site-specific–derived concentration guideline level (DCGL) requirements. By implementing MARSSIM concepts directly within RESRAD, users can now directly generate site-specific DCGL requirements and associated area factors.

1 BACKGROUND AND INTRODUCTION

The MARSSIM (Multi-Agency Radiation Survey and Site Investigation Manual) provides guidance on appropriate methodologies for establishing that dose or risk-based standards for a site contaminated with radionuclides have been achieved. The application of MARSSIM to site closure problems can be technically challenging. The three principal challenges are:

1. Determining site-specific derived concentration guideline levels (DCGLs) for a site,
2. Developing an appropriate sampling strategy to demonstrate that those DCGL requirements have been met, and
3. Implementing this sampling strategy in the field and interpreting the results obtained.

The focus of this work is to more tightly integrate tools traditionally used in MARSSIM final status survey design. The U.S. Department of Energy (DOE), the U.S. Nuclear Regulatory Commission (NRC), and other federal agencies use the RESidual RADioactive (RESRAD) codes to convert dose-based cleanup criteria to site-specific DCGL requirements. By implementing MARSSIM concepts directly within RESRAD, users can now directly generate site-specific DCGL requirements and associated area factors. RESRAD also generates generic formatted data that could also be connected to sampling program design software such as Visual Sampling Plan (VSP), COMPASS, and Spatial Analysis and Decision Support (SADA). These packages convert DCGL requirements that RESRAD produces into appropriate discrete sampling program designs on the basis of a Wilcoxon Rank Sum or Sign test. This allows users to see the implications of their DCGL requirements for final status survey designs.

1.1 MARSSIM BACKGROUND[1]

Radioactive materials have been produced, processed, used, and stored at thousands of sites throughout the United States. Many of these sites — ranging in size from federal weapons-production facilities covering hundreds of square kilometers to the nuclear medicine departments of small hospitals — were at one time or are now radioactively contaminated. The owners and managers of a number of sites would like to determine if these sites are contaminated, clean them up if contaminated, and release them for restricted use or for unrestricted public use. The Environmental Protection Agency (EPA), the NRC, and DOE are responsible for the release of sites following cleanup. These responsibilities apply to facilities under the control of federal agencies, such as the DOE and Department of Defense (DOD), and to sites licensed by the NRC and its Agreement States. Some states have responsibilities for similar sites under their control. The MARSSIM provides a nationally consistent consensus approach to conducting radiation surveys and investigations at potentially contaminated sites. This approach should be both scientifically rigorous and flexible enough to be applied to a diversity of site cleanup conditions. MARSSIM's title includes the term "survey" because it provides information on planning and conducting surveys, and it includes the term "site investigation" because the process outlined in the manual allows one to begin by investigating any site (i.e., by gathering data or information) that may involve radioactive contamination. The decommissioning that follows remediation will normally require a demonstration to the responsible federal or state agency that the cleanup effort was successful and that the release criterion (a specific regulatory limit) was met. In MARSSIM, this demonstration is given the name "final status survey." This manual assists site personnel or others in performing or assessing such a demonstration. (Generally, MARSSIM may serve to guide or monitor remediation efforts whether or not a release criterion is applied.)

As illustrated in Figure 1, the demonstration of compliance with respect to conducting surveys is comprised of three interrelated parts:

1. Translate: Translating the cleanup/release criterion (e.g., mSv/yr, mrem/yr, specific risk) into a corresponding derived contaminant concentration level (e.g., Bq/kg or pCi/g in soil) through the use of environmental pathway modeling;

[1] This section is adapted from the Marssim Manual Introduction available at http://www.epa.gov/radiation/marssim/obtain.htm.

2. Measure: Acquiring scientifically sound and defensible site-specific data on the levels and distribution of residual contamination, as well as levels and distribution of radionuclides present as background, by employing suitable field and/or laboratory measurement techniques; and

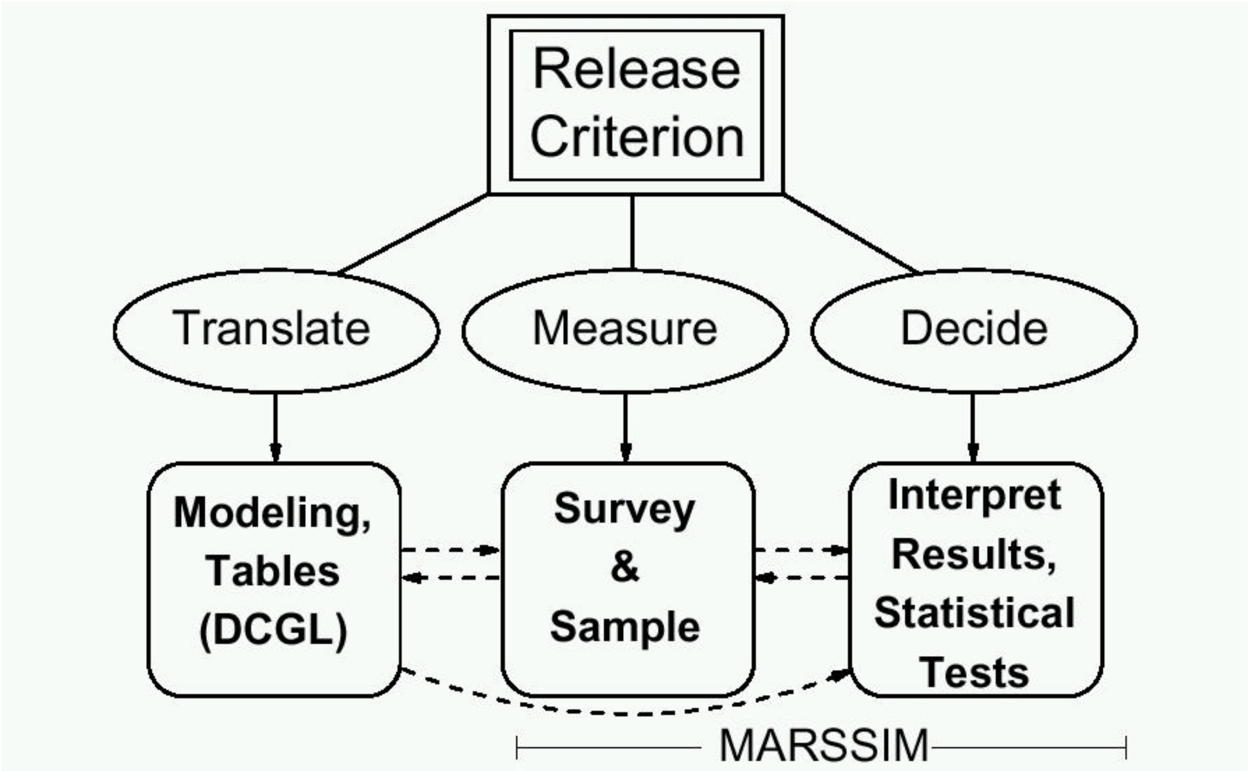

FIGURE 1 Compliance Demonstration

3. Decide: Determining that the data obtained from sampling support the assertion that the site meets the release criterion, within an acceptable degree of uncertainty, through application of a statistically based decision rule.

1.2 RESRAD BACKGROUND[2]

RESRAD is a computer model designed to estimate radiation doses and risks from RESidual RADioactive materials. RESRAD 6 is the sixth major version of the RESRAD code since it was first issued in 1989. Since that time, RESRAD has been used widely by DOE, its operations and area offices, and its contractors for deriving limits for radionuclides in soil. RESRAD has also been used by the EPA, U.S. Army Corps of Engineers, the NRC, industrial firms, universities, and foreign government agencies and institutions.

[2] This section is adapted from the RESRAD Manual Introduction available at http://web.ead.anl.gov/resrad/documents/resrad6.pdf.

The RESRAD model and computer code was developed as a multifunctional tool to assist in developing cleanup criteria and assessing the dose or risk associated with residual radioactive materials. This manual presents information on using RESRAD to:

- Compute soil guidelines (concentrations that will comply with dose- or risk-based cleanup or release requirements set forth in various federal and state regulations),

- Compute potential annual doses or lifetime risks to workers or members of the public resulting from exposures to residual radioactive material in soil,

- Compute concentrations of radionuclides in various media (air, surface water, and groundwater) resulting from residual activity in soil, and

- Support an ALARA (as low as reasonably achievable) analysis or a cost-benefit analysis that can help in the cleanup decision-making process.

"Radiation dose" is defined here as the effective dose equivalent (EDE) from external radiation and the committed effective dose equivalent (CEDE) from internal radiation (Section 2.1 in International Commission on Radiological Protection [ICRP] 1984). "Total dose" is the sum of the external radiation EDE and the internal radiation CEDE and is referred to as the total effective dose equivalent (TEDE). The dose limit or dose constraint used as a basis for the guidelines depends on the requirements of the regulation, as does the selection of the land use scenario for demonstrating compliance. Both DOE and the NRC use 0.25 mSv (25 mrem)/yr as the general limit or constraint for soil cleanup or site decontamination. The controlling principles for all guidelines are as follows. First, the annual radiation dose received by a member of the general public from residual radioactive material — predicted by a realistic but reasonably conservative analysis of the actual or likely future use of the site and calculated as the TEDE — should not exceed the dose constraint of 0.25 mSv (25 mrem)/yr. Second, doses should be ALARA when health and environmental impacts, economics, cultural and natural resources, and other appropriate factors are taken into account. All significant exposure pathways for the critical population group need to be considered in deriving soil guidelines. These pathways include the following:

- Direct exposure to external radiation from the contaminated soil material;

- Internal dose from inhalation of airborne radionuclides, including radon progeny; and

- Internal dose from ingestion of

  - Plant foods grown in the contaminated soil and irrigated with contaminated water,
  - Meat and milk from livestock fed with contaminated fodder and water,
  - Drinking water from a contaminated well or pond,

- Fish from a contaminated pond, and
- Contaminated soil.

These exposure pathways are illustrated in Figure 2. Detailed discussions of the exposure pathways considered in the RESRAD code are presented in Section 2.

Specifically, DOE Order 5400.5 (DOE 1990) and the proposed Part 834 of Title 10 of the *Code of Federal Regulations* (10 CFR Part 834; DOE 1997) require that authorized limits for control of residual radioactive materials be established and that they be established through the ALARA process. RESRAD is recommended for use in completing the pathway analyses necessary to support the development of guidelines and completion of ALARA evaluations. To complete an ALARA evaluation and select the authorized limits for a site, a number of alternative remedial actions should be evaluated against the no action alternative (DOE 2000 ALARA Guidance Volumes 1 and 2). DOE goals are to reduce potential radiation doses due to residual radioactive material to levels that are as near to background levels as is practicable. While it is not possible to reduce residual radioactive material levels to background levels in most cases, remedial actions (including necessary controls) should reduce levels such that potential doses under “actual” or “likely use” conditions would be a small fraction of the primary dose limits.

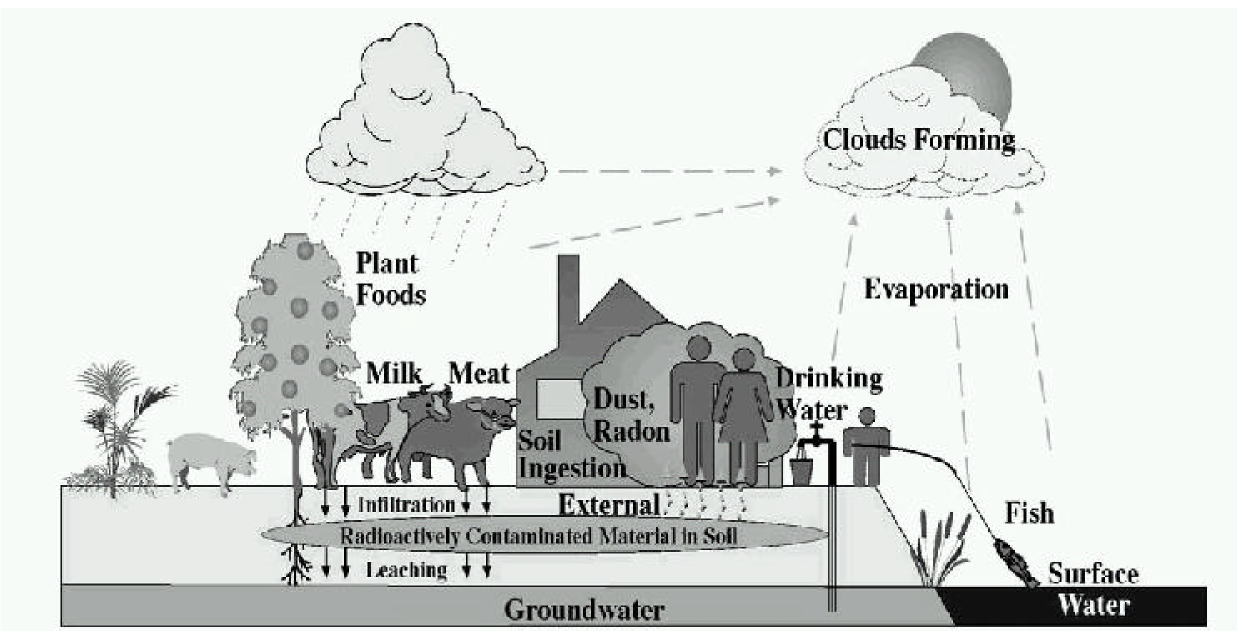

FIGURE 2 Exposure Pathways Considered in RESRAD

Models for deriving soil concentration guidelines from dose limits are simplified representations of complex processes. It is not feasible to obtain sufficient data to fully or accurately characterize transport and exposure processes. Similarly, it is not possible to predict future conditions with certainty. Consequently, the derived guideline values will include a degree of uncertainty. The built-in sensitivity and uncertainty analysis capability of RESRAD can be used to study the sensitivity of input parameters and the uncertainty of results. The sensitivity information on input parameters can be used to set priorities for the collection of data for a particular site (Cheng et al. 1991, Kamboj et al. 2002). The models and input parameters described in this manual and incorporated into RESRAD have been chosen so as to be realistic but reasonably conservative, and the calculated doses corresponding to guideline values of the radionuclide concentrations are expected to be reasonably conservative estimates (overestimates) of the actual doses. The methodology for collecting data for input into RESRAD and the ranges and typical values of input parameters are discussed in detail in the RESRAD Data Collection Handbook (Yu et al. 1993a).

The derivation of guideline values for radionuclide concentrations in soil is based on a pathway analysis method known as the concentration factor method (NRC 1977; ICRP 1979–1982; Till and Meyer 1983; National Council on Radiation Protection and Measurements 1984). With this method, the relationship between radionuclide concentrations in soil and the dose to a member of a critical population group is expressed as a sum of the products of "pathway factors." Pathway factors correspond to pathway segments connecting compartments in models of the environment between which radionuclides can be transported or radiation transmitted. Most pathway factors are assumed to be steady-state ratios of concentrations in adjoining compartments. Some are factors for conversion from a radionuclide concentration to a radiation level or radiation dose; others are use and occupancy factors that affect exposure. Each term in the sum corresponds to a pathway of connected segments. In most cases, a pathway product or pathway factor may be added, deleted, or replaced without affecting the other pathways or pathway factors. This structuring facilitates the use of alternative models for different conditions or transport processes and the incorporation of additional pathways. Thus, in most cases, RESRAD can easily be modified or tailored to model any given situation by merely adding or replacing factors or terms in the pathway sum. This report covers only those procedures for deriving site-specific guidelines for radionuclide concentrations in soil. It does not cover problems associated with procedures for collecting and interpreting field measurements of residual radioactive material or with protocols for determining whether the guidelines have been met. Guidance on these topics may be found in the RESRAD Data Collection Handbook (Yu et al. 1993b) and MARSSIM (EPA et al. 1977). Other sources of supporting information include the summary protocol for identification, characterization, designation, remedial action, and certification of Formerly Utilized Sites Remedial Action Program (FUSRAP) sites (DOE 1984, 1986a,b) and the procedures manual for remedial action survey and certification activities (Oak Ridge National Laboratory 1982).

2 METHODOLOGY

The methodology used in RESRAD to calculate the derived concentration guideline level-wide area (DCGL-W) and area factors consists of the following processes:

- A user sets up a deterministic scenario and site description.

- When the RESRAD-MARSSIM button is selected, RESRAD will calculate many dose estimates for a unit of each radionuclide. Each dose estimate uses different contaminated areas selected from a log-uniform distribution to cover the range from 1 m^2 to the size the user specifics in the site characterization. All other RESRAD input parameters except the length parallel to aquifer flow are kept at the user's deterministic values. The length parallel to aquifer flow will be correlated with the contaminated area being considered.

- The peak dose from a unit contamination of each radionuclide for a given contaminated area is stored in a database.

- The peak dose at the largest contaminated area is assigned to the DCGL-W.

- The peak doses at each of the smaller contaminated areas are divided by the DCGL-W to derive the area factor for each nuclide and area.

- These results are placed into both a spreadsheet and/or COMPASS-formatted database.

The user could also perform this set of procedures without using the RESRAD-MARSSIM button. The process would just be less automated. However, the user might want to make a set of assumptions that are not consistent with this methodology; for example, probabilistic analysis of distribution coefficients might also be considered. In this case, the user could set up a probabilistic RESRAD run for each of the contaminated areas considered (remembering to correlate the length parallel to aquifer flow). Care should also be taken if the contaminated fraction of foodstuffs is altered from default values. These default values are set to automatically adjust the fraction based on the amount of food that can be farmed on the considered area. After running each RESRAD case, the user could extract some selected measure of the dose estimate (e.g., peak of the mean, mean of the peak, 95 percentile of the peak, etc.). These doses could be divided by the dose estimate for the largest contaminated area considered (DCGL) to give the area factor curve as a function of area and nuclide.

3 USER'S GUIDE

3.1 AVAILABILITY AND INSTALLATION

To properly implement the RESRAD-COMPASS connection for facilitating MARSSIM analysis, both computer codes, RESRAD and COMPASS, must be installed on the same computer. A version of RESRAD that contains a connection to COMPASS is available at www.ead.anl.gov/resrad. The COMPASS software can be obtained at http://www.orau.gov/essap/marssim.htm#Compass. To install these codes, run the installation files and follow the on-screen instructions, which will tell you the steps to take to finish the installation.

3.2 OBTAINING DCGLS FROM RESRAD

The modified version of RESRAD for MARSSIM analysis looks very similar to the standard RESRAD code, with minor differences (Figure 3). There are two additional buttons on the button bar that are used to run MARSSIM analysis and view MARSSIM graphics. There is also an option to run MARSSIM analysis from the File menu. In addition to the shortcut button, the user may also access MARSSIM graphics from the View menu and on the Results tab in the Navigator form.

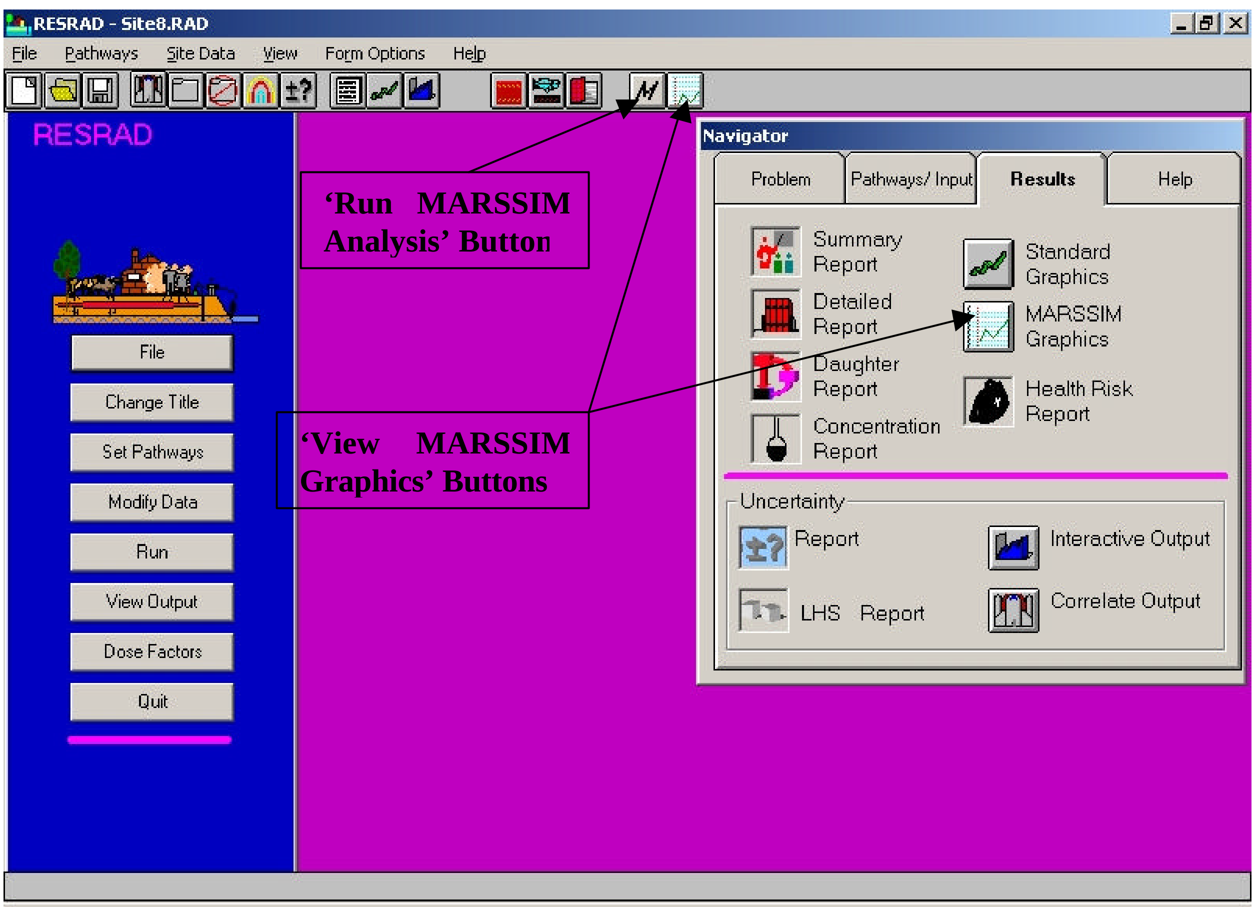

FIGURE 3 Modified RESRAD Interface for MARSSIM Analysis

To obtain the DCGLs necessary for COMPASS input, the user must set up a deterministic scenario and site description in RESRAD. Once the RESRAD input file is set up, the MARSSIM analysis is ready to be run by clicking on the "Run MARSSIM Analysis" button. Following the completion of the RESRAD-MARSSIM analysis run, the RESRAD-MARSSIM Graphics window appears (Figure 4).

There are several plot options available to the user. Area, Area Factor, DCGL, and Dose may be plotted versus each other for each of the radionuclides in the case. The X and Y axes may be scaled linearly and logarithmically.

The data from the RESRAD run can now be exported to both Excel and COMPASS by clicking on the appropriate Area Factor Export button. After choosing to export to Excel, a new workbook will open containing the Area Factor data. The export to COMPASS option will bring up the RESRAD/COMPASS Data Export Wizard (Figure 5). This wizard guides the user through the process of importing the RESRAD-derived area factors and DCGLs into COMPASS.

After setting up the site description, the user is given the option to use the DCGLs generated from RESRAD or use a user-defined value for the DCGL for each radionuclide (Figure 6). The user cannot modify area factors.

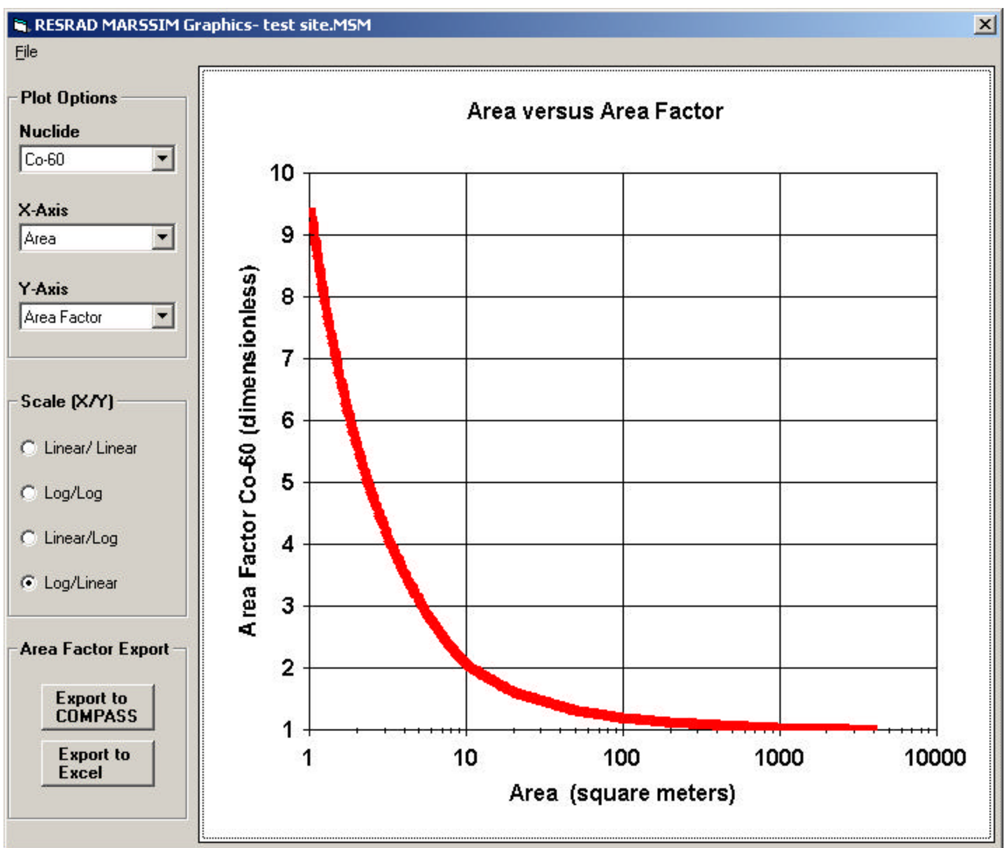

FIGURE 4 RESRAD-MARSSIM Graphics Window

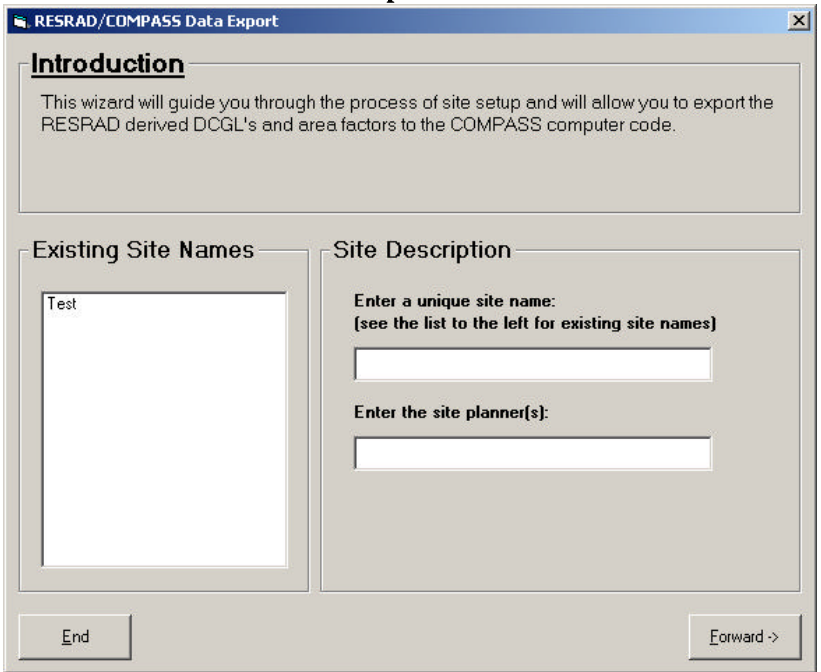

FIGURE 5 RESRAD/COMPASS Data Export Wizard

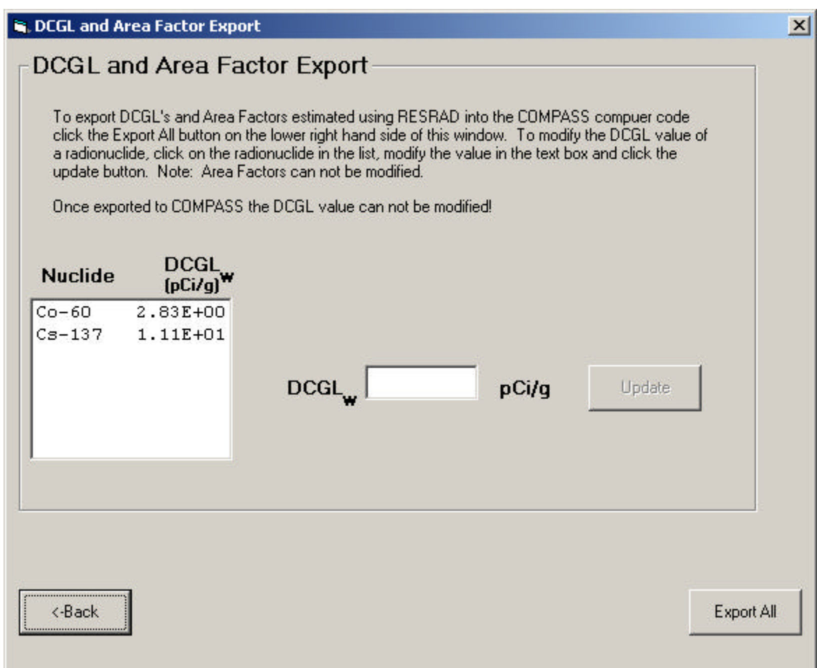

FIGURE 6 DCGL and Area Factor Export Screen

The site has now been set up to use in COMPASS. To use the site in COMPASS, the user chooses the DQO (Data Quality Objective) Wizard for Surface Soil Assessment option on the Site Planning tab (Figure 7).

Next, the site setup from the RESRAD/COMPASS Data Export Wizard will be available from the list of sites available (Figure 8).

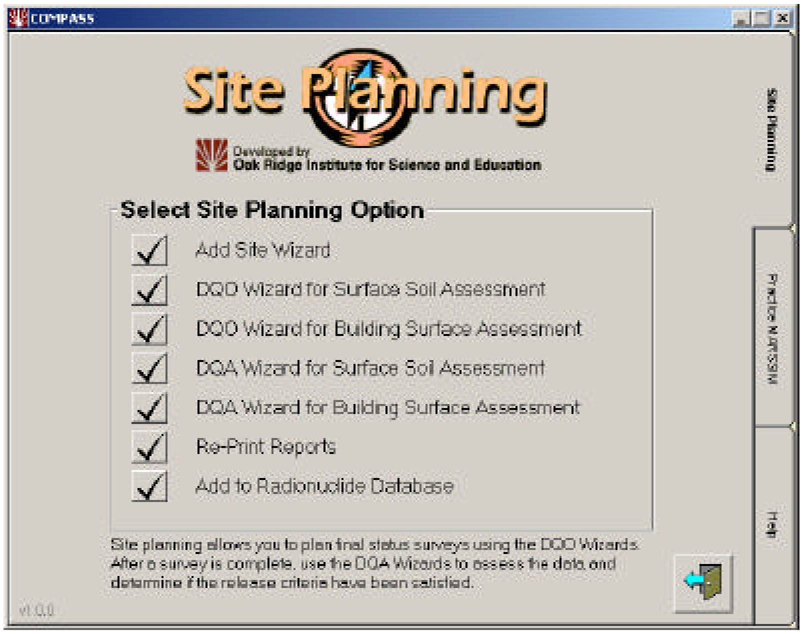

FIGURE 7 Site Planning Option Screen in COMPASS

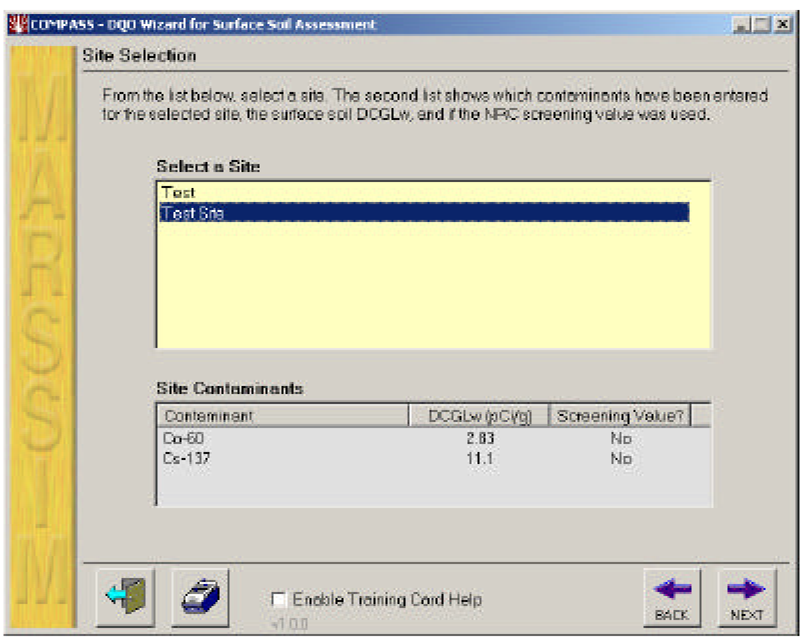

FIGURE 8 Site Selection Screen in COMPASS

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